A multilevel and dynamic model of intragroup conflict and decision making: application of agent-based modeling

Wu, Jiunyan; Sekiguchi, Tomoki

Wu and Sekiguchi *Frontiers of Business Research in China* (2020) 14:2
https://doi.org/10.1186/s11782-019-0070-1

Frontiers of Business
Research in China

RESEARCH Open Access

A multilevel and dynamic model of intragroup conflict and decision making: application of agent-based modeling

Jiunyan Wu* and Tomoki Sekiguchi

* Correspondence: wu.yan.62z@st.kyoto-u.ac.jp
Graduate School of Economics, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto 606-8501, Japan

Abstract

Although intragroup conflict has both multilevel and dynamic natures, less attention has been paid to establishing a holistic model of intragroup conflict that emerges across levels and unfolds over time. To address this research gap, we extend the multilevel view of intragroup conflict (Korsgaard et al. 2008) to develop a multilevel and dynamic model of intragroup conflict that explicitly includes (1) the role of time and (2) the feedback loop to encompass the dynamic aspect of intragroup conflict. We further instantiate the extended model in the context of team decision-making. To achieve this and systematically examine the complex relationships, we use agent-based modeling and simulation (ABMS). We directly investigate how two types of intragroup conflict—task and relationship conflict—interplay with cross-level antecedences, interrelate and develop over time, and affect team outcomes. This study adds to the intragroup conflict research by extending the field with multilevel and dynamic views.

Keywords: Intragroup conflict, Multilevel, Dynamics, Agent-based modeling and simulation (ABMS), Team decision-making

Introduction

Conflict is multidimensional (Jehn 1995) and dynamic (Greer et al. 2008; Jehn and Mannix 2001) and involves multilevel interplay (de Dreu and Gelfand 2007; Korsgaard et al. 2008; Lee et al. 2018). Scholars have historically conceptualized and measured intragroup conflict at the team level (Jones et al. 2019; Korsgaard et al. 2008); however, relatively little attention has been paid to multilevel aspects or to the dynamic view of conflict. For example, most empirical studies used Jehn's (1995) framework to measure cross-sectional employees' perceptions of team-level task or relationship conflict by asking questions such as "How much conflict about the work you do is there in your work unit?" (Jehn 1995) and implied a single-level approach (Humphrey et al. 2017; Korsgaard et al. 2008). One primary limitation of such explanatory collectivism is that it depends on the assumption of individual homogeneity (Humphrey and Aime 2014). As a result, although dyadic and team conflicts are social phenomena emerging and manifesting at higher levels of analysis (Jehn and Bendersky 2003), research has neglected the multilevel nature of intragroup conflict with its emergence processes and dynamic evolution, despite their criticality for team functioning.

Based on prior work that addressed a process view, multilevel aspects, and the dynamic nature of intragroup conflict (e.g., Pondy 1967), Korsgaard et al. (2008) developed a multilevel model of intragroup conflict by integrating the individual, dyadic, and team levels of intragroup conflict analysis. This model demonstrates that intragroup conflict can result from an individual's perceptions and behaviors, dyadic interactions, or within-team interactions with respect to various task conditions. The current study aims to build on and extend Korsgaard et al.'s (2008) original model to explicitly encompass the dynamic aspect of conflict. By allowing for the dynamics of conflict, we further recognize that a team is not a single-level static entity but rather a complex, multilevel, dynamic entity. We explicitly characterize the dynamic aspect of conflict (e.g., the role of time and recursive relationships) following recent studies on intragroup conflict (e.g., Cronin and Bezrukova 2019; Jones et al. 2019).

This study instantiates a multilevel and dynamic model of intragroup conflict in the context of small-team decision-making. We focus on team decision-making because this is a primary area of research in intragroup conflict (de Dreu and Weingart 2003). Indeed, team decision-making is ubiquitous and relevant to business. For example, marketing teams evaluate the available options and decide how to enter a market, while corporate boards develop and agree on corporate strategies and resource allocation. Specifically, rather than finding out *if* intragroup conflict is evoked, we focus on the interplay between two types of conflict, namely task and relationship conflict and cross-level antecedents, to see *how* intragroup conflicts emerge and evolve over time, as well as their effects on team decision-making, as measured by decision commitment, decision quality, and team consensus. We achieve this goal through the lens of an agent-based model and simulation (ABMS), which can incorporate many types of non-linear effects and co-evolved relationships among team members, environments, and interactions (Smith and Conrey 2007). It can be used to directly examine and analyze the dynamic aspect of conflict across levels over time. Applying ABMS thus provides advantages over traditional research designs for capturing the emergence and evolution of conflict.

This study contributes to conflict research in several ways. First, we extend Korsgaard et al.'s (2008) model to explicitly include the dynamic aspect of intragroup conflict. Second, we instantiate the extended model in the context of team decision-making. Although the links between several cross-level antecedents with intragroup conflict have been studied (for a detailed review on intragroup conflict, see de Dreu and Weingart 2003; de Wit et al. 2012), research using a dynamic multilevel view of intragroup conflict that connects relevant constructs in the context of decision-making is scant. We believe that our model can provide an end-to-end perspective for exploring complex links. Third, our study examines complex relationships with intragroup conflict over time and helps to unpack the black box of intragroup conflict with a granular look, through a visualized presentation of non-linear intragroup conflict development. Lastly, we attest to the advantages of applying a direct quantitative method, namely ABMS, to capture and understand the dynamics of emergent phenomena. In summary, this study extends the current research of intragroup conflict to be further integrally embedded with multilevel and dynamic views.

Theoretical background and hypothesis development

The multilevel and dynamic view of intragroup conflict

Among the few studies that have addressed the multilevel aspect and the dynamic nature of intragroup conflict, Jehn and Mannix (2001) challenged most of the prior research that focused only on static levels of conflict while neglecting the different conflict patterns that might occur over time. They encouraged scholars to consider research questions concerned with *how much* and *when*, rather than *if* certain conflicts occur. By studying 193 employees in 31 branch offices, Lee et al. (2018) investigated how two types of conflict at two levels (the individual and team levels) influence individual team commitment. Humphrey et al. (2017) presented a dyadic view of conflict for team performance over time, focusing on the dyad at the center of intragroup conflict, instead of measuring team-level perceptions.

Korsgaard et al. (2008) proposed one of the first integrated theoretical frameworks to depict the emergence of conflict; it consists of three linked processes that lead to conflict, namely inputs, behavior, and sense making. In their model, Korsgaard et al. (2008) postulated that group conflict reflects a process of compiling interweaving individual differences, states, behaviors, and sense making; interpersonal contexts, interactions, and sense making; and team-level contexts, interactions, and collective sense making (Greer and Dannals 2017), and they addressed the multilevel nature of intragroup conflict, including bottom-up, top-down, and cross-level relationships and their emergence processes. In other words, group conflicts emerge from the dyadic interactions that emerge from individual differences and behaviors. This was opposed to simply focusing on within-level relationships and conflicts, understood as team-level phenomena in most previous research (Cronin and Bezrukova 2019; Korsgaard et al. 2008). Thus, we build on Korsgaard et al.'s (2008) theoretical framework to examine the multilevel aspect of intragroup conflict.

Given that one of our study objectives is to scrutinize the dynamics of intragroup conflict, which is critical but missing in the current research (Cronin and Bezrukova 2019), we thus extend Korsgaard et al.'s (2008) model to capture the essence of team dynamics by explicitly including the roles of time and recursive relationships, or feedback loops (see Fig. 1). We therefore reflect Cronin et al.'s (2011) study of team dynamics which suggests considering two group dynamic features: (a) memory (which is time associated—meaning what happens next depends on the current conditions) and (b) recursion (which is the possibility that causal chains feed back upon themselves).

First, team research largely overlooks time (Cronin et al. 2011). Intragroup conflict could arise over time (Cronin and Bezrukova 2019) through multiple episodes (Korsgaard et al. 2008). In a longitudinal study utilizing 51 three-person groups, Jehn and Mannix (2001) concluded, "If we had used a one-time measure of conflict, the results and their interpretation would have been very different" (p. 248). Korsgaard et al. (2008) considered the role of time as a future direction for study because the processes (e.g., behavior and sense making) that lead to conflict represent actions undertaken by individuals, resulting in the emergence of conflict or its change over time. From a multilevel perspective, the role of time catalyzes the emergent phenomena to be manifested at a higher level (Kozlowski and Klein 2000). As time unfolds, team interactions can amplify small changes in individual behaviors or dyadic interactions, which can cause large changes to manifest as a higher-level collective phenomenon (Kozlowski and Klein 2000). Therefore, we extend Korsgaard et al.'s (2008) model to include a fourth level—time, which has a critical role and overarches the aforementioned processes and multilevel relationships.

Second, conflict change can rely on feedback loops between outcomes and processes (Cronin and Bezrukova 2019). However, Cronin and Bezrukova (2019) challenged most conflict research as lacking an articulation of feedback structures. Likewise, Kozlowski

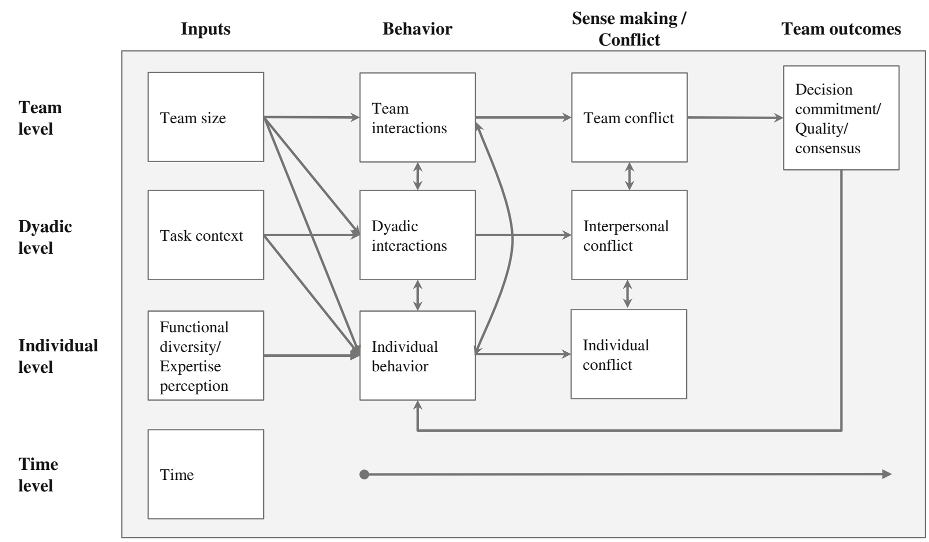


Fig. 1 A multilevel dynamic model of intragroup conflict. *Notes*. The model is built on and extended Korsgaard et al.'s (2008) multilevel model of intragroup conflict

(2015) argued that team dynamics have largely been treated as static in research and that one of the reasons why is because the current studies on teams are based on input-process-out, which is a static model (McGrath 1964) without feedback loops. Theory (e.g., Pondy 1967), nevertheless, suggests that such recursive relationships do exist. A conflict escalation is a kind of self-reinforcing feedback loop (Cronin et al. 2011). Korsgaard et al. (2008) acknowledged the importance of recursive relationships but did not depict the explicit relationships in their model, in keeping with their focus on the multilevel nature of group conflict and in the interest of parsimony. Therefore, we extend Korsgaard et al.'s (2008) model to include a feedback loop that links team outcomes back to individual behaviors, explicitly indicating their recursive relationship. By doing so, we are in line with suggestions from Ilgen et al. (2005) and Humphrey and Aime (2014). Our extended model displays a dynamic framework of input-mediator-output-input and emphasizes a micro-dynamics-oriented approach with which to comprehend a multilevel (i.e., individual, dyadic, team-level, and cross-level) and multi-period (i.e., time-associated) framework.

Fig. 1 shows our overall model. In multilevel antecedents, we focus on functional diversity and expertise perception as individual-level antecedents, task context as a dyadic-level antecedent, and team size as a team-level antecedent of intragroup conflict. Team members interact intensively while exchanging viewpoints with each other for a decision-making task, which induces intragroup conflict. As time unfolds, intragroup conflict interrelates, carries over, and dynamically evolves; intermediate team outcomes reciprocally influence individual perceptions and behavior. Eventually, a team performs and reaches its objectives or results, namely decision commitment, decision quality, and team consensus. Notably, team outcomes, which Korsgaard et al.'s (2008) model did not illustrate, are included in our extended model to reflect the consequences of intragroup conflict and the recursive linkages.

The effects of individual−/dyadic−/team-level antecedents on intragroup conflict

Intragroup conflict Intragroup conflict is broadly defined as "the degree to which members have real or perceived incompatible goals or interests" (Greer and Dannals 2017: p. 318). Two of the most researched forms of conflict are task conflict and relationship conflict (Cronin and Bezrukova 2019; de Wit et al. 2012). Task conflict (Jehn 1995) or cognitive conflict (Amason 1996) pertains to task-oriented disagreements and debates over alternatives that are related to a team's tasks, regarding how work is being done (Amason and Sapienza 1997). Relationship conflict (Jehn 1995) or affective conflict (Amason 1996) pertains to interpersonal incompatibilities and tensions with underlying individual-oriented issues, such as dislike or annoyance (Jehn 1995; Kurtzberg and Mueller 2005). Jehn (1997) and Bendersky and Hays (2012) introduced the third and fourth types of conflict—process conflict and status conflict, respectively. Much of the previous research has focused on team-level conflict arising in contexts such as decision-making, team projects, and production (de Dreu and Weingart 2003) or has distinguished among different types of conflict (Korsgaard et al. 2008).

To instantiate our multilevel, dynamic model and apply ABMS to the study, we focus on two primary types of conflict—task conflict and relationship conflict, in keeping with parsimony. Task and relationship conflicts have also been the focus of studies investigating the temporal dynamics of conflict (e.g., Humphrey et al. 2017; Maltarich et al. 2018). In our ABMS setting, any member can freely exchange ideas with peers, and all members are equal ex ante. In other words, we assume that there is no concern about disagreements regarding the logistics of task completion, work delegation, work arrangements, or members' relative positions of respect.

Individual-level antecedent Functional diversity—the degree to which members come from and represent different functional backgrounds (e.g., engineering, sales, or marketing)—has been found to promote cognitive diversity and thus task conflict (Lovelace et al. 2001; Mooney et al. 2007; Pelled et al. 1999). Members from diverse functional backgrounds possess varied skill sets and approach issues from different viewpoints. Intragroup conflict may arise when different experiences and views are expressed or discussed (Pelled et al. 1999). Because task conflict promotes the exchange of ideas, teams with functional diversity can synthesize diverse viewpoints into well-reasoned decisions (Amason 1996). In fact, Amason (1996) asserted that task conflict is inevitable in decision-making because executives view environments differently and thus express varying perspectives.

Although functional diversity can often be recognized as an information resource that benefits team creativity (van Knippenberg and Hoever 2018) and has a positive effect on innovation (Camelo-Ordaz et al. 2005), studies show that increased conflict, stemming from functional diversity, inhibits team processes and effectiveness (e.g., Pelled et al. 1999). It is prone to inducing affective conflict (Cai et al. 2013) and interfering with the seeking of agreements and strategic consensus among top management teams (TMTs) (Knight et al. 1999).

When teams possessing functional diversity or differing expertise interacts over time, the members will create and revise their perceptions of "who knows what" (Wegner

1987, 1995; Wegner et al. 1985). Gradually, team members' understandings of "who knows what" will become more refined and consensual (Lewis and Herndon 2011), implying that expertise within teams is being recognized. Palazzolo et al. (2006) used a computational simulation and suggested that the initial level of accuracy in expertise recognition impacts emergent communication. A higher initial level of accuracy of expertise recognition will result in a higher average communication density. Consequently, familiarity among team members increases through increased team interactions and communication, enhancing the members' ability to recognize the right expertise (Palazzolo et al. 2006).

Once members progressively form a perception of "who knows what" and recognize the expert(s), the emergence of expert recognition can shift the balance of individual influence on group decisions in the expert's favor (Tajeddin et al. 2012). In a study of laboratory settings, Bonner et al. (2002) showed that teams working on moderately difficult problems give more weight to input from identified experts in team decision-making. Therefore, when team members debate task-oriented alternatives from different perspectives, the members tend to agree with the recognized experts if a suitable solution is not obviously found, suggesting that fewer task conflicts will evolve. Thus, we offer the following hypothesis:

Hypothesis 1*: While having more functional diversity will increase task conflict, higher accuracy of expertise recognition will develop into less task conflict.*

Dyadic-level antecedent Task context pertains to the structural influence of how team members interact. It sets the stage for shaping potential intragroup conflict (Korsgaard et al. 2008). If a team's assignment is clear or relatively routine, then too much debate about a task or specific process will be counterproductive and interfere with the group's functioning (Jehn et al. 1999). Additionally, when tasks are relatively independent, team members can perform individually without much dyadic or team interactions or communication. This implies that the potential for stimulating conflict is low (Neck et al. 1996).

Contrarily, when members encounter non-routine, interdependent tasks without clear goals or with goals incompatible with the members' interests, team members require more input from each other to coordinate interdependent tasks. As team members engage in more interactions, debates can be provoked on topics such as their preferences or objections due to their differing perspectives, which will accordingly induce intragroup conflict. A meta-analysis by de Dreu and Weingart (2003) showed that the negative effects of conflict on member satisfaction and team performance are more pronounced when team tasks are more interdependent.

In a context of team decision-making for which a team's task is to select, by some consensus, a preferred alternative (McGrath 1984), members whose ideas on a particular issue are challenged by others may feel upset, tension, or animosity and will likely attribute this task-related argument as a personal attack (Guenter et al. 2016; Jehn 1997; Pelled et al. 1999). Thus, decision-making can be deemed as more a quasi-rational than a fully rational process (Mooney et al. 2007). Hence, we offer the following hypothesis:

Hypothesis 2*: In an interdependent decision-making task, dyadic members must interact intensively and exchange viewpoints, which induces intragroup conflict.*

Team-level antecedent In addition to the attributes of task context shaping both dyadic and team interactions, as delineated above, we choose to focus on team size to represent team-level social context inputs (Korsgaard et al. 2008). Team size is chosen because it "parsimoniously represents a team's structural and compositional context" (Amason and Sapienza 1997: p.499) and is considered part of a team's characteristics, structure, and composition (Cohen and Bailey 1997; Gist et al. 1987).

Team size is a key variable that influences team dynamics and performance (Brewer and Kramer 1986). Several studies have shown that team size is positively associated with both task and relationship conflict (e.g., Amason and Sapienza 1997; Mooney et al. 2007). Increased team size provides an opportunity for more information to be shared and offers the potential to add diverse perspectives to decision-making (van Knippenberg et al. 2004). Increased team size, however, can bring more divergent feelings, personal goals, or biases linked to social categorization (Tajfel and Turner 1979); thus, it is difficult for larger teams to communicate, coordinate, and develop cohesion (e.g., Katzenbach and Smith 1993; Mooney et al. 2007), potentially resulting in more relationship conflict.

Moreover, smaller teams may be able to coordinate or communicate effectively with a higher communication density (e.g., Michinov and Michinov 2009; Palazzolo et al. 2006). Palazzolo et al. (2006) contended that smaller teams have a higher average communication density than larger teams do; in turn, a higher average communication density will lead to greater accuracy in expertise recognition over time. In other words, a team's size is negatively related to the accuracy of expertise recognition, which is then negatively associated with task conflict, as argued above. Taking a different view of expertise recognition associated with team size and conflict, we thus reach the same hypothesis as Amason and Sapienza (1997) and offer the following:

Hypothesis 3*: The larger the team size, the more task and relationship conflict will emerge; the smaller the team size, the less both conflicts will emerge.*

Intragroup conflict interrelation and conflict inertia

Regarding how task and relationship conflicts are interrelated, we acknowledge that these two types of conflict often co-exist and are highly intertwined, with mean-corrected correlation ranging between 0.54 and 0.84 (de Dreu and Weingart 2003). By testing seven models of the potential association between two conflicts, Choi and Cho (2011) supported the view that relationship conflict increases subsequent task conflict through negative group effect. Still, the majority of research has studied how task conflict leads to relationship conflict (e.g., Jehn and Mannix 2001; Mooney et al. 2007; Parayitam and Dooley 2007; Pelled et al. 1999; Peterson and Behfar 2003; Simons and Peterson 2000). Therefore, we set the direction of influence from task conflict to relationship conflict in our computational model.

Few longitudinal studies have emphasized the dynamic nature of intragroup conflict or studied the patterns of conflict in high-/low-performing teams (Jehn and Mannix

2001), the degree to which different forms of intragroup conflict perpetuate themselves (Greer et al. 2008), or the relationships between different types of conflict over time (Humphrey et al. 2017). However, we argue that empirical evidence has neglected to theorize on and examine the role of conflict inertia (Cronin and Bezrukova 2019) or conflict continuity (Jones et al. 2019) in current conflict research.

Inertia, referred to as a factor's capacity to retain its state over time, is essential to enhancing the understanding of conflict dynamics (Cronin and Bezrukova 2019). Inertia "characterizes how the effects of what has happened in the past are retained and carried forward to influence the future" (Cronin and Bezrukova 2019: p. 778). The role of conflict inertia echoes the concept of conflict continuity, suggesting that conflict remains stable at its given level (Jones et al. 2019). For example, task conflict, at the beginning, may set the tone for the team and continue to foster openness for debate about the task (Jehn 1997). Similarly, relationship conflict in the early stages of the team discussion can be retained and accumulated to negatively lead to more relationship conflict later, creating a vicious cycle of intragroup conflict. Most longitudinal work, which is largely influenced by conceptualizing and operationalizing intragroup conflict as aggregated to a single point of time, tends to assume that the conflict that occurs early will naturally carry over to the next stage to shape the level of conflict incurred later. As such, although "being" existent, conflict inertia has not explicitly been examined but rather assumed, controlled, or neglected (Cronin and Bezrukova 2019). Aligned with Cronin and Bezrukova's (2019) viewpoint, we believe that precisely capturing conflict inertia can contribute to our understanding of the dynamic aspect of intragroup conflict. As a result, the snapshot view of intragroup conflict can be connected from one point to the next through the effects of conflict inertia, and a whole series of intragroup conflicts can evolve. Therefore, we propose the following hypothesis:

Hypothesis 4*: Conflict occurring within a team in one time period will carry over to the next time period, causing conflict inertia.*

The effects of intragroup conflict on team-level outcomes

Regarding the effects of conflict upon team functioning, relationship conflict (e.g., de Dreu and Weingart 2003; Jehn 1995) is generally seen as damaging. Yet, the findings regarding the effects of task conflict have been mixed. The results have included negative consequences (de Dreu and Weingart 2003), positive consequences (Jehn 1995; Jehn et al. 1999; Puck and Pregernig 2014), and no significant consequences (de Wit et al. 2012). In an attempt to explain the mixed findings of previous studies, Jehn and Bendersky (2003) represented a conflict-outcome moderated model from a contingency perspective, whereby the effects of each type of conflict depend on contextual factors. In a meta-analysis, de Wit et al. (2012) found that a primary moderator of task conflict and group performance was the degree to which relationship conflict co-occurred with task conflict. In the context of team decision-making that represents a series of non-routine tasks, we consider three team-level outcomes to be critical: decision commitment, decision quality, and team consensus. We specifically delineate the effects of task conflict on these three team outcomes.

Task conflict mainly enhances team performance through constructive discussions on different viewpoints and increased mutual understanding through which joint actions are formed. In debating task-oriented content via frank discussions, task conflict enables a "safe" setting for team members to synthesize conflicting alternatives into a joint decision (Schweiger and Sandberg 1989). Team members become more committed to the final decision when they freely discuss, share their thoughts, or have the opportunity to voice their perspectives (Amason 1996; Erez et al. 1985; Parayitam and Dooley 2009). In other words, decision commitment is likely to increase when task conflict is interpreted as constructive and useful (Olson et al. 2007; Parayitam and Dooley 2009). For similar reasons, task conflict should also enhance decision quality due to the synthesis of diverse perspectives (Amason 1996). Interestingly, Parayitam and Dooley (2011) found curvilinear (inverted U-shaped) relationships between cognitive conflict and decision quality, and between cognitive conflict and decision commitment, implying that too much task conflict is harmful.

Without decision consensus, even a high-quality proposal will be futile. Although task conflict can enhance decision consensus by contributing to mutual understanding, we support Jehn and Mannix's (2001) view and believe that time can play a critical role in dissipating the positive side of task conflict in the decision-consensus process. Jehn and Mannix (2001) demonstrated that high-performing groups have higher levels of task conflict in the middle of team interactions than at the beginning or end. They argued that task conflict that occurs too late in a team's interactions may reduce consensus and threaten implementation. Therefore, we propose the following hypothesis:

Hypothesis 5a*: Teams with higher levels of relationship conflict will have lower levels of team outcomes in decision commitment, decision quality, and decision consensus.*

Hypothesis 5b*: Teams with higher levels of task conflict will have higher levels of team outcomes in both decision commitment and decision quality but a lower level of decision consensus.*

Non-linear development of intragroup conflict

From the multilevel perspective, emergent phenomena originating from lower-level processes can be conceptualized as two idealized endpoints, namely composition and compilation forms (Kozlowski and Klein 2000). While composition forms are homogeneous, linear, and convergent, compilation forms are heterogeneous, non-linear, and divergent (Kozlowski et al. 2013). As intragroup conflict is deemed to be the experience between or among members with incompatible goals or interests (Korsgaard et al. 2008), conflict is not always similarly shared. Every team member could have unequal perceptions and experience (e.g., some members may be more involved in the conflict while others passively observe it) and contribute differently to the team-level perception of intragroup conflict (Jones et al. 2019). This suggests that various compositions of conflict perception may exist within a team over time (Korsgaard et al. 2014). In contrast to the mean conflict level (i.e., the aggregate level or composition forms of conflict in a team), Jehn et al. (2010) used the concept of conflict asymmetry at both the individual and team levels to explain how asymmetries in perceptions can influence team outcomes and individual satisfaction. In this sense, intragroup conflict can be better described as emerging through a compilation process (Greer and Dannals 2017; Korsgaard et al. 2008).

Given that teams are living and adaptive systems, dyadic/team interactions can dynamically interplay within and across the individual, dyadic, and team levels to form intragroup conflicts and affect team outcomes accordingly (Korsgaard et al. 2008). As "change is both the result of a process and a process itself" (Cronin et al. 2011: p.577), intermediate team outcomes can reciprocally influence individual perceptions and behaviors. As a result, the compilation forms of intragroup conflict can emerge, develop at different rates, and evolve and devolve with respect to the dynamics of team interactions over time. This implies that the development of intragroup conflict is not fixed but rather uniquely variable at any point of time. Thus, we hypothesize the following:

Hypothesis 6: *The development of intragroup conflict is not stable, and it fluctuates in various non-linear forms.*

Methods

Agent-based modeling and simulation

We built an ABMS to yield a multilevel and dynamic model of intragroup conflict in the context of small team decision-making. Researchers from a variety of disciplines are recognizing and using ABMS, a bottom-up computational technique, to study a range of emergent behaviors and phenomena (Hughes et al. 2012) and to simulate dynamic large-scale, and complicated systems, such as in organizational behavior (Abar et al. 2017). Through building three core blocks into the ABMS—contexts (e.g., tasks, social networks or organizational structures), agents (e.g., individuals or groups), and interactions (e.g., self-governing or adaptive behavior due to learning from others)—the ABMS can simulate generative outcomes to yield higher-level and non-linear phenomena to meet the research purposes (Billari et al. 2006).

Essentially, the philosophy of ABMS, starting with modeling individual agents for emergent phenomena to be manifested at a higher level, is aligned with the core concept of the multilevel perspective (Kozlowski and Klein 2000). While the emergence process is rarely examined directly but rather inferred based on cross-sectional data (Kozlowski 2015), ABMS offers advantages over traditional research designs for capturing emergence. By modeling simple behavioral rules (i.e., through a set of mathematical equations and logic) originating from a lower level of individuals, ABMS helps to directly trace the non-linear development, and to elaborate why/how a target phenomenon emerges and evolves at a higher level. By creating a theoretically-based model, ABMS allows researchers to systematically vary a great number of built-in parameters/assumptions operating under different scenarios, namely unconstrained simulations, that are challenging to proceed with using traditional approaches (e.g., field studies and lab experiments) (Davis et al. 2007). Additionally, when building an ABMS, most researchers are required to have already considered the time factor (e.g., as a proxy for days, months, years, or any virtual periods) and explored the development of research interest over time. Clearly, ABMS also has potential limitations, such as the difficulty of identifying the correct balance between simplicity and complexity (Smith and Conrey 2007), the issue of external validation (Davis et al. 2007; Hughes et al. 2012), or making false assumptions in modeling (Davis et al. 2007).

Although the ABMS method can incorporate all kinds of non-linear or co-evolved relationships among individuals, teams, and environments, we followed Smith and

Conrey's (2007) recommendation of the so-called KISS (keep it simple, stupid) principle, based on the belief that "the most interesting analytical results are obtained when simple micro-level dynamics produce complex patterns at the macro-level" (Billari et al. 2006: p. 4). We used the ABMS-NetLogo platform (Wilensky 1999) available at ccl.northwestern.edu/netlogo.

Model description

Contexts. We modeled a small team working together to execute a series of decision-making tasks (see Table 1), which required the team members to reach a team consensus about a certain solution with no demonstrably right answer (McGrath 1984). The assignment was defined as a problem set with 10 problem aspects (an arbitrary value). In each round of discussion for decision-making, members were required to evaluate individual proposals against the elaborated one and make a joint decision for each problem aspect. After 20 rounds of discussion (an arbitrary value, as a proxy for one meeting session), we assumed that team members would have had sufficient interactions through elaboration and evaluation that would potentially evoke individual-/dyadic-/team-level task and relationship conflicts that would impact team outcomes. Progressively, certain levels of decision commitment, decision quality, and team consensus could be reached.

We further considered the effect of time on intragroup conflict. After 10 rounds (i.e., representing the midpoint of a meeting), we reflected on the influence of time on

Table 1 The computational model of intragroup conflict for small team decision-making

A proposer's processes

1. Identify a problem aspect
2. Present own proposal to the identified problem aspect

Other members' processes

3. Evaluate own proposal to the identified problem aspect against the presented one
   a. If the proposer is recognized as a subject expert, go to Step 4a
   b. If both proposal discrepancy is less than 0.5 (an arbitrary value) and the perceived level of the proposer's expertise is higher than own expertise, go to Step 4a
   c. If none of above, go to Step 4b
4. Dyadic interactions due to the outcome of Step 3
   a. Support the presented proposal and do not evoke any task conflict, go to Step 6
   b. Reject the presented proposal and evoke a task conflict between the proposer and the evaluator, go to Step 6
5. Dyadic interactions due to the outcome of Step 6
   a. If the presented proposal is supported jointly, members (except the proposer) adjust individual proposals towards the supported proposal and upgrade the perceived level of the proposer's expertise, go to Step 7
   b. If a presented proposal is rejected jointly, team members downgrade the perceived level of the proposer's expertise, go to Step 7

Team processes

6. Make a team census decision whether or not to support the presented proposal to the identified problem aspect
   a. If more than half of members opt for the proposal, a team will jointly support the presented proposal to the identified problem aspect, go to Step 5a
   b. If less than half of members opt for the proposal, a team will jointly reject the presented proposal to the identified problem aspect, go to Step 5b
7. Continue the next problem aspect, go to Step 1
8. Finish a round of discussion if 10 problem aspects are all covered
9. Finish a decision-making task after 20 rounds of team discussion

conflict (Kurtzberg and Mueller 2005) and applied a decayed function to the level of intragroup conflict. In practice, a team may spend hours intensively debating several options. After a harsh discussion, a pleasant social gathering such as a coffee break can alleviate stressfully emotional experiences during the session and allow the team atmosphere to become lively again in the next session.

Agents. We defined agents (i.e., team members, in our study) as possessing three characteristics: (a) individual proposals for 10 problem aspects; (b) a structure of expertise recognition, which is similar to the transactive memory structure (Wegner 1987), or a perception of "who knows what," including a self-directory and an others-directory; and (c) job-related knowledge, skills, and attitudes (KSAs) for each of the 10 problem aspects. We operationalized functional diversity in terms of the deviations of individual proposals on 10 problem aspects, to reflect differences in members' beliefs and preferences about the assignment options. Characteristics (a) and (b) were adjusted according to the consequent interactions. Characteristic (c) is a fixed value used to determine who the absolute experts are for the 10 problem aspects. The value is later used to compare the final structure of expertise recognition and to compute the accuracy level of expertise recognition (described later).

Each member has a proposal about how he/she views the 10 problem aspects. Initially, individual proposals are set as a normal distribution function with a mean of 0.5 and a standard deviation that varies in one of three conditions (i.e., high/medium/low scale) and are updated according to team interactions. For example, if a greater number of members supports a proposal for a specific aspect, the members (except the proposer) will adjust their individual proposals to move toward the supported proposal by 0.1 in scale (an arbitrary value). However, the individual proposals will remain unchanged if a team consensus cannot be reached for the specific proposal.

As defined by Wegner et al. (1985), members update their individual perception of "who knows what" through interactions with others. We modeled that members will update their perceptions of the specific proposer depending on whether the proposal is jointly supported. For example, if most members support an elaborated proposal for a specific problem aspect, the members will upgrade the perception directory of the specific proposer by 0.05 in scale (an arbitrary value) and downgrade their self-directory by a 0.05 scale (an arbitrary value).

Interactions. We integrated two levels of interactions: (a) dyadic interactions and (b) team interactions. In the beginning of each round, a member was randomly assigned to elaborate on his/her proposal to a specific problem aspect for the other members. The other members were to generate dyadic interactions with the proposer. The participants compared the variance of the elaborated proposal and then judged whether or not to support the specific proposal according to the degree of their proposal discrepancy and the perception of their own and the proposer's relative expertise. Because task conflict is defined as disagreements about task-oriented issues such as appropriate choices of alternative options (Jehn 1995), dyadic interactions and sense-making processes can induce task conflict, which can be accumulated between dyadic members over a discussion.

For team-level interactions, a specific proposal was then evaluated by following the consensus approach (McGrath 1984) to decide on joint support or rejection of the elaborated proposal. According to the outcome of the team consensus, the intermediate result reciprocally influenced each member; members adjusted their individual proposals and their perceptions of expertise as delineated above. Then, the next problem aspect was selected, and the same processes were repeated. A round of team discussions was deemed completed after 10 problem aspects were elaborated and evaluated. In total, 20 rounds of team decision-making were designated.

After each round of decision-making, we measured the team-level task conflict by averaging the individually accumulated number of task conflicts. We posited that a member would have sufficient interactions with other members during the rounds of team discussion and that individually accumulated task conflict was an indicator of how each member evaluated the team-level task conflict.

Regarding team-level relationship conflict, we aligned with most prior research to define an influence from task conflict to relationship conflict. In the computational model, we integrated a signature study by Simons and Peterson (2000) in which intragroup trust moderated the relationship between task conflict and relationship conflict. In their model, task conflict, intragroup trust, and task conflict×intragroup trust had significant effects on relationship conflict, with *b*-coefficients of 0.52, − 0.35, and − 0.10, respectively. Following Aiken and West's (1991) process, we constructed a regression line [also illustrated by Simons and Peterson (2000)] and computed team-level relationship conflict accordingly by assuming the same level of intragroup trust ($M = 29.64$, $SD = 3.18$) in our computational small teams.

Procedures

Based on an experimental approach, we systematically examined the effects of individual-/dyadic-/team-level antecedents on intragroup conflict and the resultant team functioning. The approach consisted of three scenarios of initial deviation among individual proposals (i.e., representing the individual functional diversity: high/medium/low scale, 0.5, 0.3, and 0.1, respectively) times three scenarios of expertise recognition (high/medium/low scale, 0.75, 0.5, and 0.25, respectively) times three scenarios of small team size (three, five, and seven members) times three scenarios of intragroup trust (one standard deviation below/the same as/above mean scale, namely − 1, 0, and 1). We varied the scenarios to create 81 total conditions (i.e., $3 \times 3 \times 3 \times 3 = 81$ conditions). Although computer simulation can be any size, we ran 30 simulations for each condition. The results revealed enough similarity to indicate that no additional runs would be productive, and having a sample size of 30 is considered sufficient for the central limit theorem to hold. Designing such a scope with conventional experimental approaches would be very challenging. Nevertheless, direct investigation through the use of a computational model and simulations is a valuable method (Kozlowski and Chao 2012).

Based on the findings of the extant literature as well as our professional judgment, we made necessary assumptions to set the stage and define the model logic and then allowed the team members to adapt to the changes as the simulations unfolded. The key variables, processes, assumptions, and parameters of the computational model can be found in Table 2.

Outcome measurements

We measured three team outcomes: decision commitment, decision quality, and team consensus in the final round (i.e., when time steps = 20). First, we combined the research findings by Parayitam and Dooley (2009) and the ABM-generated outcomes (i.e., the magnitude of team-level task and relationship conflict) to compute the decision commitment. Parayitam and Dooley (2009) surveyed 980 hospitals and investigated the interplay between two types of conflict and two types of trust as well as the associated impacts on decision-making. Task conflict and relationship conflict were found to have significant effects on decision commitment, with standardized regression coefficients of 0.63 and − 0.15. Second, we operationalized decision quality in terms of the final accuracy of expertise recognition, employing the rationale that the higher the accuracy in identifying the right expertise for a specific problem, the better the decision quality will be. The final accuracy of expertise recognition was computed as the percentage of the number of perceived experts (i.e., based on the collective perception after 20 rounds of interactions) correctly matching the absolute experts [i.e., based on the individuals' characteristics (c)] out of 10 problem aspects. For example, a 50% recognition accuracy in the final round meant that five experts were correctly identified out of 10 problem aspects due to their having the highest level of KSAs for the respective problem aspects. Third, the decision consensus was computed as the total number of supported proposals (out of 10 problem aspects) in the range of 0 to 10.

Results

Table 3 represents the descriptive statistics and correlations for all of the study variables. The path relationships within the research model were analyzed with structural equation modeling (SEM) using the R lavaan package. The results of the SEM are shown in Fig. 2. The goodness-of-fit statistics indicated a good fitting, SRMR = 0.02, AGFI = 0.93, GFI = 0.97, CFI = 0.97, TLI = 0.94. The model also had sufficient explanatory power, as it explained 89% of the variance in decision commitment, 38% of the variance in the final accuracy of expertise recognition (i.e., decision quality), and 28% of the variance in decision consensus.

Hypothesis 1 predicted that higher functional diversity would increase task conflict yet higher accuracy of expertise recognition would develop into less task conflict. As shown in Fig. 2, the relationship between the initial deviation of individual proposals and task conflict was positive and significant ($\beta = 0.79$). However, the initial accuracy of expertise recognition had a significant negative relationship with task conflict ($\beta = -0.18$). Thus, Hypothesis 1 was supported.

From the perspective of how team size affects expert recognition and the resultant effects on conflict, Hypothesis 3 predicted that a larger (smaller) team size would increase (decrease) both types of conflict. Fig. 2 shows a significant positive relationship between team size and task conflict ($\beta = 0.18$). However, we did not find support for team size's relationship with relationship conflict.

Hypothesis 4 predicted that both task and relationship conflict occurring during one time period would carry over to subsequent time periods, causing conflict inertia. As shown in Fig. 2, task conflict at round 5 was significantly related to task conflict at round 15 ($\beta = 0.54$), and relationship conflict at round 5 was significantly related to relationship conflict at round 15 ($\beta = 0.20$). The results indicated that over time, task

Table 2 The summary of key model variables/processes, assumptions and corresponding parameters in ABMS

Model variables/Processes	Assumptions	Corresponding parameters in ABMS
1. Members		
1.1 A set of individual proposals to 10 problem aspects of a task	Members possess a set of initial proposals to 10 problem aspects and update their proposals according to the temporal outcome of team consensus due to the feedback loop	An initial normal distribution function with the mean of 0.5 and a standard deviation in one of three scenarios (high/medium/low scale, namely a 0.5/0.3/0.1 standard deviation) to represent functional diversity
1.2 A set of expertise perception of "who knows what," including self- and others-perception	Members possess a set of initial expertise perception of "who knows what" (Wegner 1987) and update their perception according to the temporal outcome of team consensus due to the feedback loop	Random variables between 0 and 1; the higher the value, the higher perception of expertise The initial accuracy of expertise recognition in one of three scenarios (high/medium/low scale, namely 75%/50%/25%) to represent expertise perception
1.3 A set of job-related knowledge, skills and attitudes (KSAs) to 10 aspects of a task	Member possess a set of fixed job-related KSAs to 10 problem aspects	Random variables between 1 and 100; the higher the value, the higher KSAs to a problem aspect. The variables used to determine who the absolute experts are for the 10 problem aspects
2. Dyadic interactions		
2.1 Proposal evaluation	Members compare own proposals against the presented one and evoke dyadic task/relationship conflict if there exists a disagreement about the proposals or the perception of expertise	Members (except the proposer) compare the variance between own proposal and the presented one Members opt to support or reject the presented proposal depending on the proposal discrepancy (< 0.5) and the relative levels of perceived expertise to the specific problem aspect If members do not support the presented proposal, dyadic task conflict as well as relationship conflict will be evoked
3. Team interactions		
3.1 Problem aspect identification	In each round of discussion, 10 problem aspects of a task are identified one by one	In each round of discussion, a team identifies 10 problem aspects one by one In total, 10 problem aspects of a task are identified in each round
3.2 Proposal elaboration	For each problem aspect, a team randomly assigns a member to elaborate his/her proposal to the identified problem aspect	A team member is randomly assigned to present his/her proposal to the identified problem aspect for others' evaluation (as described in 2.1)
3.3 Team consensus	Team decision-making process follows the consensus approach (McGrath 1984) to determine a joint decision whether or not to support the presented proposal to the specific problem aspect	A team will support the presented proposal to the specific problem aspect if more than half of members opt for the proposal (due to dyadic interactions as described in 2.1) A team will reject the presented proposal to the specific problem aspect if less than half of members opt for the proposal (due to dyadic interactions as described in 2.1)
3.4 Intragroup conflict	Intragroup conflict originates from lower-level processes and manifests across levels to make an impact on team functioning (Korsgaard et al. 2008; Kozlowski and Klein 2000)	In each round of discussion, the magnitude of team-level task conflict is measured by averaging individually accumulated number of task conflicts due to dyadic interactions, and divided by the maximum number of possible task conflicts The relationship of intragroup task

Table 2 The summary of key model variables/processes, assumptions and corresponding parameters in ABMS *(Continued)*

Model variables/Processes	Assumptions	Corresponding parameters in ABMS
		conflict, intragroup trust and intragroup relationship conflict follows the study by Simons and Peterson (2000) and the magnitude of team-level relationship conflict is then computed accordingly
4. Team outcomes		
4.1 Decision commitment	Decision commitment is one of key criteria to measure the success of team decision-making	The relationship of intragroup task conflict, relationship conflict, and decision commitment follows the study by Parayitam and Dooley (2009) and the magnitude of decision commitment is then computed accordingly in the final round of discussion (i.e., when time steps = 20)
4.2 Decision quality	Decision quality is one of key criteria to measure the success of team decision-making	Operationalized in terms of the final accuracy of expertise recognition Measured as the percentage of the number of perceived experts correctly matching to the absolute experts out of 10 problem aspects in the final round The value in the range of 0% to 100%; the higher the value, the higher decision quality
4.3 Decision consensus	Decision consensus is one of key criteria to measure the success of team decision-making	Measured as the total number of supported proposals (out of 10 problem aspects) in the final round The value in the range of 0 to 10; the higher the value, the higher decision consensus

conflict was more stable than relationship conflict. Thus, the results supported Hypothesis 4. Within the same decision-making round, task conflict was modeled to influence relationship conflict, following the study by Simons and Peterson (2000).

Hypothesis 5 predicted that higher levels of relationship conflict would have negative effects on team outcomes and that higher levels of task conflict can result in higher levels of team outcomes in decision commitment and decision quality but not decision consensus. Although we did not find support for Hypothesis 5a about the effect of relationship conflict on decision quality (i.e., the final accuracy of expertise recognition) or on decision consensus, there was partial support for Hypothesis 5b about the relationship between task conflict and team outcomes. As shown in Fig. 2, the relationship between task conflict and decision commitment was positive and significant ($\beta = 0.98$), as we modeled it based on the research outcomes by Parayitam and Dooley (2009), but contrary to our prediction, task conflict was negatively related to decision quality. The relationship between task conflict and decision consensus ($\beta = -0.35$) was also negatively significant.

We then examined Hypothesis 2, which stated that intragroup conflict can be induced in an interdependent task, such as team decision-making. Fig. 3 clearly demonstrates that once dyadic members started to interact, such as by comparing the discrepancies between dyadic proposals and the perceptions of relative expertise,

Table 3 Means, standard deviations, and correlations

		M	SD	1	2	3	4	5	6	7	8	9	10
1	Initial deviation of individual proposals	0.30	0.16	–									
2	Initial accuracy of expertise recognition	0.50	0.20	0.00	–								
3	Team size	5.00	1.63	0.00	0.00	–							
4	Intragroup trust	0.00	0.82	0.00	0.00	0.00	–						
5	Task conflict (at round five)	12.76	1.85	0.79**	−0.18**	0.18**	0.01	–					
6	Relationship conflict (at round five)	8.61	1.90	0.40**	− 0.09**	0.10**	− 0.82**	0.51**	–				
7	Task conflict (at round 15)	6.84	0.55	0.76**	−0.12**	0.08**	0.02	0.80**	0.39**	–			
8	Relationship conflict (at round 15)	5.53	0.32	0.67**	−0.10**	0.07**	−0.07**	0.72**	0.51**	0.89**	–		
9	Decision commitment (at round 20)	1.06	0.23	0.77**	−0.11**	0.05*	0.14**	0.81**	0.28**	0.93**	0.79**	–	
10	Decision quality, namely accuracy of expertise recognition (at round 20)	0.66	0.19	−0.09**	0.54**	−0.30**	0.00	−0.22**	− 0.11**	−0.16**	− 0.14**	−0.15**	–
11	Decision consensus (at round 20)	3.56	1.73	−0.47**	0.05*	−0.09**	−0.01	− 0.46**	−0.22**	− 0.49**	−0.44**	− 0.59**	0.03

Notes. $n = 2430$ teams; * $p < 0.05$, ** $p < 0.01$.

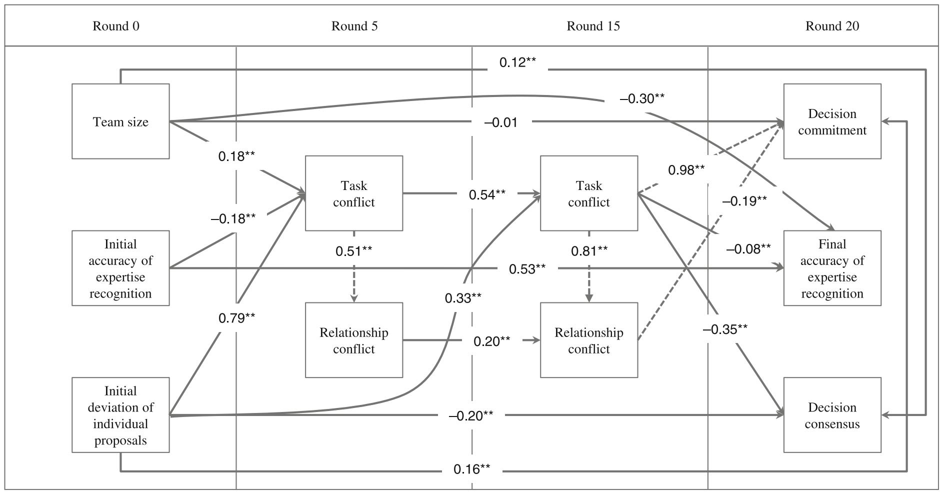
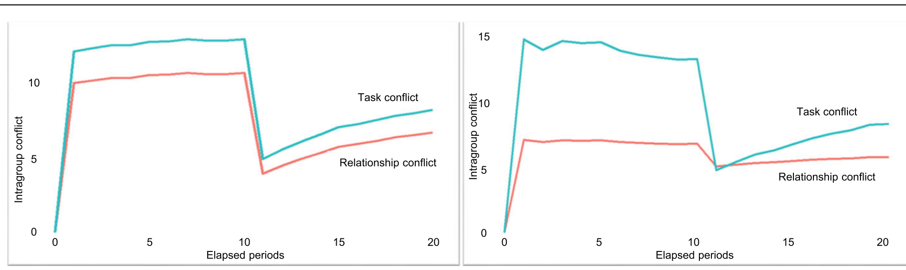


Fig. 2 Path analysis results.*Notes.* ** $p < 0.01$; dotted lines represent the relationship analysis defined based on the literature findings

intragroup conflict emerged across levels and unfolded over time. The results provided support for Hypothesis 2.

Hypothesis 6 posited the non-linear development of intragroup conflict over time. Fig. 3 shows two examples of non-linear development due to different individual characteristics and dyadic/team interactions across levels over time. One would expect that as the diversity of individual proposals varies further or when both the initial recognition of expertise and trust are low, teams may confront more task conflict, which would then induce more relationship conflict, implying that both types of conflict emerge and escalate over time [see Fig. 3(a)]. Alternatively, it can be the case that when most of the individual proposals initially share a certain degree of commonality or when the level of expertise recognition and trust are higher, the evolution of conflict can be moderately converged over time [see Fig. 3(b)]. Moreover, Fig. 4 shows another aspect of the non-linear development of intragroup conflict and further addresses an operational issue of inadequate sampling rates (Kozlowski 2015). As the evolution of conflict is unstable and fluctuates in non-linear forms, it is inadequate to simply project the changes to conflict phenomena based on a one-time measurement. In the case of only sampling at



(a) The initial deviation of individual proposals (= 0.50); the initial accuracy of expertise recognition (= 0.25); the intragroup trust (= one standard deviation below)

(b) The initial deviation of individual proposals (= 0.30); the initial accuracy of expertise recognition (= 0.5); the intragroup trust (= one standard deviation above)

Fig. 3 The non-linear development of two types of intragroup conflict over time *Notes*. In the scenario of team size (= five members) points A and B (e.g., two experiments conducting in a multi-sectional approach), researchers may wrongly conclude that the level of intragroup conflict remained the same over time and neglect rich information, such as downward and upward trends or a non-linear development of conflict, as shown in Fig. 4. These results provided strong support for Hypothesis 6.

Discussion

Contributions

First, our model extends Korsgaard et al.'s (2008) original model and explicitly features the dynamics of intragroup conflict by integrating two important aspects: the role of time and the recursive relationship. To extend Korsgaard et al.'s model, we position a fourth element, time, which overarches both the processes and the multilevel relationships contributing to the emergence and development of intragroup conflict. Highlighting the recursive relationship by linking the team outcomes back to individual behavior reflects the endogenous change of conflict (Cronin and Bezrukova 2019). As a result, we present intragroup conflict as reflecting the dynamic processes that emerge at the team level, instead of relying on static events or team-level constructions at the onset of the team's formation.

We further extend the previous research by paying greater attention to the multilevel and dynamic aspects of intragroup conflict. In a highly cited study based on a sample of 45 teams, Pelled et al. (1999) presented an integrative model of the relationships among diversity, conflict, and performance. However, we argue that their approach (e.g., the measurement of constructs primarily through questionnaire items) might be unable to fully capture the nature of conflict. Following Korsgaard et al. (2008), we view intragroup conflict as emerging and manifesting at higher levels of analysis. The other strength of our model is that we examine the dynamics of intragroup conflict and its evolution over time (see Fig. 3). By doing so, we acknowledge that teams are complex interactive entities, which echoes the calls from scholars to study team dynamics from

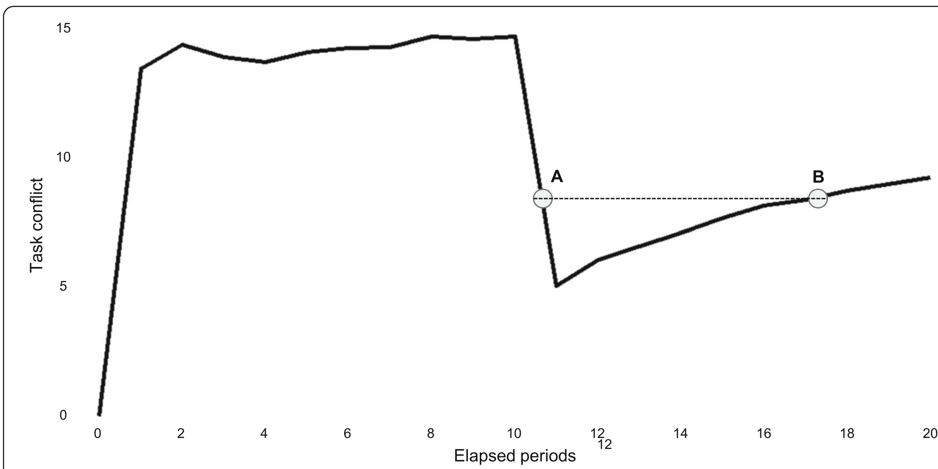


Fig. 4 The evolution of task conflict over time *Notes.* Assuming that at two periods of time A and B, the level of conflict was measured and a linear trend was projected; in the condition of team size (= seven members); the initial accuracy of expertise recognition (= 0.25); and the initial deviation of individual proposals (= 0.5)

longitudinal and non-linear perspectives (e.g., Cronin et al. 2011; Humphrey and Aime 2014; Kozlowski 2015) and to study the dynamics of intragroup conflict from a multi-level perspective (e.g., Korsgaard et al. 2008).

Second, we instantiate the extended model in a business-relevant context of a small team making a decision. We build the first computational model to connect the individual-/dyadic-/team-level antecedents to interactive processes, two primary types of intragroup conflict, and three team outcomes; we further conduct simulations and analyze the model's results accordingly. The model explicitly includes a feedback loop indicating, for example, that an intermediate perception of expert recognition could influence the social interactions in the next round of the decision-making process. Furthermore, unlike previous studies using a single time-point design, we directly address the time-sensitive nature of conflict by making team members engage in a series of decision-making processes. In our study context, team members were required to discuss 10 problem aspects in 20 rounds of decision-making. Such a dynamic approach opens new doors for studying conflict evolution and its associated effects on decision-making via temporally based new constructs, such as the frequency or duration of conflict (Cronin and Bezrukova 2019).

Third, our results demonstrate multilevel and dynamic aspects of intragroup conflict. Our path model (see Fig. 2) supports the hypotheses that connect the effects of individual-/dyadic-/team-level antecedents on intragroup conflict. It displays the paradox of task conflict. For example, on one hand, task conflict at time 15 had a strong, positive relationship with decision commitment ($\beta = 0.98$). On the other hand, task conflict had a significantly negative relationship with decision consensus ($\beta = -0.35$). This implies that although task-related debates are necessary to allow members to voice their viewpoints and thus enhance decision commitment, a well-rounded proposal becomes void without team consensus. As shown by Jehn and Mannix (2001), in high-performing teams, a moderate level of task conflict at the midpoint of group interactions encourages needed discussions; task conflict that occurs too late may reduce consensus. Moreover, consistent with a previous study (Knight et al. 1999), our results indicate that in addition to being mediated by intragroup conflict, functional diversity is negatively related to decision consensus ($\beta = -0.20$).

To provide evidence of the dynamic aspect of conflict evolution, the results offer a granular view of intragroup conflict with a visualized presentation, such as a non-linear development of conflict convergence or escalation (see Fig. 3). Moreover, the analysis supports our argument that due to conflict inertia, intragroup conflict that occurs within a team at one time period will carry over to subsequent time periods. It sounds obvious, but this is a fact often ignored by scholars in assuming the dynamics of phenomena. We explicitly hypothesize and examine conflict inertia. The results indicate that task conflict was more stable than relationship conflict over time, consistent with other research (Jones et al. 2019; Maltarich et al. 2018); however, research does not discuss the effects of conflict inertia.

Fourth, our study attests to the advantage of applying a direct quantitative method, largely signified by ABMS, to capture and understand the phenomena's dynamics (Kozlowski and Chao 2012; Kozlowski et al. 2013). Our results provide visualized and traceable evidence of non-linear changes in conflict. Considering a similar scale of study deployed with traditional techniques (e.g., an experiment of 81 conditions to analyze intragroup conflict in field studies or lab experiments), the data collection and processing in multi-period research can become unmanageable (Humphrey and Aime 2014).

In Fig. 4, our results clearly confirm a troublesome issue: If one measures the levels of task or relationship conflict in a cross-sectional approach that is, for example, not aligned with the fluctuations of a phenomenon of interest and that only measures two widely spaced events, one would be unable to precisely capture the process shift and may make conclusions with compromised or opposite interpretations (Kozlowski 2015). The operational issue of inadequate sampling rates can become more pronounced as more scholars urge longitudinal studies and the incorporation of a conceptual consideration of the time construct when developing a theory or measurement (e.g., Kozlowski 2015).

Computer simulation is recognized as a third way of conducting science (Axelrod 1997), in addition to theoretical analysis (i.e., a deduction approach) and empirical analysis (i.e., an induction approach). ABMS, as one type of computer simulation, allows the simulations to generate rather than deduce the consequences of these processes (Harrison et al. 2007). Nevertheless, despite the contrasting conceptions between computational methodology and traditional techniques, in most cases, both can be complementary (Hughes et al. 2012; Smith and Conrey 2007) and integrated into research designs (Kozlowski et al. 2013). Our study offers a promising alternative to move the research further toward integrating ABMS with the extant studies to yield an integral model of intragroup conflict (see Fig. 5).

Practical implications

Due to the compilation process of intragroup conflict originating from a lower level of individuals, managers should realize that any subtle change (e.g., changes to membership expertise or team size) or a change in just one team member's behavior could trigger another transition or fluctuation of intragroup conflict, which can then reach another dynamic equilibrium over time. To underscore the dynamic aspect of conflict, we have also shown the non-linear development of intragroup conflict. We suggest that managers first identify whether dyadic members are already experiencing a certain level of conflict and manage it actively upfront. Jehn et al. (2013) developed a model for conflict escalation showing that an interpersonal and dyadic conflict can spread to other members and infect all of the team members over time through a process of conflict contagion. Early managerial intervention into dyadic conflicts or short-term disagreements will better resolve and benefit the team's functioning before other team members can be infected and the conflict escalates into a full-blown team conflict (Jehn et al. 2013), or before the conflict is retained in a team and influences subsequent conflicts (e.g., Humphrey et al. 2017). When team discussion becomes overheated, a period of separation to allow team members a break may be a wise strategy for managers to avoid escalating intragroup conflict [see Fig. 3 (a)].

In sum, as today's workforce becomes more diverse and mobile in complex business environments (e.g., with members equipped with differing expertise moving in and out of project teams), managers need to consider a new set of questions about how to maximize the upside potential of a highly diverse workforce while minimizing the downside risks in arousing intragroup conflicts. Furthermore, conflict management can

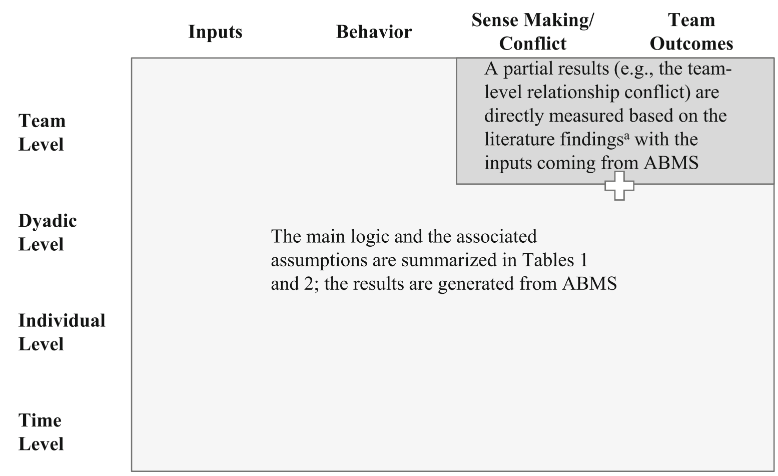


Fig. 5 An integral approach of combining ABMS with literature findings. *Notes.* [a]The studies by Simons and Peterson (2000) and Parayitam and Dooley (2009)

become even harder in a global setting across cultural differences or geographic dispersion. For example, Furumo (2009) found that conflict is more likely to arise in virtual teams, while Stark and Bierly III(2009) found that the extent of virtualness worsens the negative effect of relationship conflict on team member satisfaction.

Limitations and future research directions

One central limitation of this study is that the validity and generalizability of ABMS to represent a theoretical model depend on the assumptions built into the model (Davis et al. 2007; Hughes et al. 2012). Consequently, the interpretations are limited to the assumptions and parameters embedded within the computational model. Different assumptions or parameters, such as implementing other team processes for decision-making or constructing different formulas to define the complex relationship between a task and relationship conflict as well as related effects on team outcomes, may produce different results and interpretations. In this study, we adhere to the KISS principle and conceptual parsimony to model the most fundamental processes of intragroup conflict. However, the computational model and simulations may not present all of the complex conditions of intragroup conflict in actual teams or workplaces.

Another limitation of this study is that we directly applied the outcomes of two studies (Parayitam and Dooley 2009; Simons and Peterson 2000), which used two different conflict scales, to compute intragroup conflict, and integrated it into our computational model. Specifically, we defined the relationship between a task and relationship conflict based on the study by Simons and Peterson (2000) and their effects on decision commitment based on the study by Parayitam and Dooley (2009), rather than allowing team-level relationship conflict to emerge and develop over time in our model. By doing so, the method may have introduced further constraints to the study (e.g., regarding the accuracy of team-level relationship conflict). This may be the reason that there are no obvious relationships between relationship conflict and either cross-level antecedences or team outcomes. Nevertheless, we see the benefits of the integral approach, and to our best knowledge, we are the first to demonstrate a promising methodology of synthesizing ABMS with the relevant literature in studying intragroup conflict in team decision-making. Furthermore, given that our main goal was to develop a dynamic multilevel model and apply it in a certain business context, we do not intend to include an exhaustive list of cross-level antecedents to conflict or all potential directions of intragroup conflict interrelations.

There are several promising areas in need of future research. First, built on our study, one direction is to continue to carry on Davis et al.'s (2007) roadmap of virtual experimentation to build a novel theory. Davis et al. (2007) offered several approaches for effective simulation: (a) varying the values of constructs that were held constant in the initial stage, (b) unpacking key theoretical constructs, (c) varying assumptions, and (d) adding new features to the computational presentation. In addition, a final step of validating the model with empirical data (Davis et al. 2007) could be promising.

Second, as global teams with mixed nationalities as well as cross-country collaborations become common, examining and including the impacts of cultural differences is another promising direction for future research. For example, Qian et al. (2013) surveyed the chief executive officers and chief technology officers of 122 Chinese firms and did not find that TMTs' functional diversity was associated with cognitive or affective conflict. They argued that because harmony is emphasized in China, there is more room for top managers to appreciate and accommodate each other's unique functional backgrounds in a non-hostile situation. We deem that cultural perspectives can influence the assumptions and parameters in the computational model and trigger a different mechanism of intragroup conflict through which to influence team functioning.

Conclusions

Understanding intragroup conflict and ways to better manage it is critical to team functioning. Inspired by a multilevel view of intragroup conflict (Korsgaard et al. 2008) and studies of team dynamics (Cronin and Bezrukova 2019; Cronin et al. 2011; Humphrey and Aime 2014), we extended Korsgaard et al.'s (2008) original model to encompass both the multilevel and dynamic aspects of intragroup conflict. By applying ABMS, we examined the emergence and development of intragroup conflict and its effects on team decision-making. Our integrative model and computational simulations helped to unpack the black box of intragroup conflict and to display the non-linear evolution of intragroup conflict. It is unlikely that we can fully explore the complex relationships among individual-/dyadic-/team-level antecedents, team social interactions, the evolution of intragroup conflict over time, or team outcomes unless these conditions can be systematically investigated through an aligned set of lenses: specifically, a concerted theory, novel measurement, and rigid analysis.

Abbreviations

ABMS: Agent-Based Modeling and Simulation; KISS principle: Keep It Simple, Stupid principle; KSAs: Knowledge, Skills and Attitudes; SEM: Structural Equation Modeling; TMT: Top Management Team

Acknowledgements

Not applicable.

Authors' contributions

JW designed the work, created the ABM programing codes and was a major contributor in drafting the manuscript. TS made contributions to the conception, interpreted the datasets and substantively revised the work. Both authors read and approved the final manuscript.

Authors' information
Mr. Jiunyan Wu is a doctoral program student in Graduate School of Economics, Kyoto University, Japan. His research mainly focuses on the organizational behavior, human resources management, and team dynamics.
Professor Dr. Tomoki Sekiguchi is a Professor and doctoral supervisor in Graduate School of Management, Kyoto University, Japan. His research mainly focuses on the international human resource management and cross-cultural organizational behavior.

Funding
Not applicable.

Availability of data and materials
The datasets generated and analyzed during the current study are available in the Google drive repository, https://drive.google.com/drive/folders/1rtnCRZ8ktjFQQzErAv-KXw8gbIWlUDVB?usp=sharing
The ABM programming codes used during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare that they have no competing interests.

Received: 23 May 2019 Accepted: 9 December 2019
Published online: 31 December 2019

References

Abar, S., Theodoropoulos, G. K., Lemarinier, P., & O'Hare, G. M. P. (2017). Agent based modelling and simulation tools: A review of the state-of-art software. *Computer Science Review, 24*, 13–33.
Aiken, L., & West, S. (1991). *Multiple regression: Testing and interpreting interactions*. Newbury Park: Sage.
Amason, A. C. (1996). Distinguishing the effects of functional and dysfunctional conflict on strategic decision making: Resolving a paradox for top management teams. *Academy of Management Journal, 39*(1), 123–148.
Amason, A. C., & Sapienza, H. J. (1997). The effects of top management team size and interaction norms on cognitive and affective conflict. *Journal of Management, 23*(4), 495–516.
Axelrod, R. (1997). *The complexity of cooperation: Agent-based models of competition and collaboration* (Vol. 3). Princeton: Princeton University Press.
Bendersky, C., & Hays, N. A. (2012). Status conflict in groups. *Organization Science, 23*(2), 323–340.
Billari, F. C., Fent, T., Prskawetz, A., & Scheffran, J. (Eds.). (2006). *Agent-based computational modelling: Applications in demography, social, economic and environmental sciences*. Heidelberg, Germany: Physica-Verlag.
Bonner, B. L., Baumann, M. R., & Dalal, R. S. (2002). The effects of member expertise on group decision-making and performance. *Organizational Behavior and Human Decision Processes, 88*(2), 719–736.
Brewer, M. B., & Kramer, R. M. (1986). Choice behavior in social dilemmas: Effects of social identity, group size, and decision framing. *Journal of Personality and Social Psychology, 50*(3), 543–549.
Cai, L., Liu, Q., & Yu, X. (2013). Effects of top management team heterogenous background and behavioural attributes on the performance of new ventures. *Systems Research and Behavioral Science, 30*(3), 354–366.
Camelo-Ordaz, C., Hernández-Lara, A. B., & Valle-Cabrera, R. (2005). The relationship between top management teams and innovative capacity in companies. *Journal of Management Development, 24*(8), 683–705.
Choi, K., & Cho, B. (2011). Competing hypotheses analyses of the associations between group task conflict and group relationship conflict. *Journal of Organizational Behavior*, *32*(8), 1106–1126.
Cohen, S. G., & Bailey, D. E. (1997). What makes teams work: Group effectiveness research from the shop floor to the executive suite. *Journal of Management, 23*(3), 239–290.
Cronin, M. A., & Bezrukova, K. (2019). Conflict management through the lens of system dynamics. *Academy of Management Annals, 13*(2), 770–806.
Cronin, M. A., Weingart, L. R., & Todorova, G. (2011). Dynamics in groups: Are we there yet? *Academy of Management Annals, 5*(1), 571–612.
Davis, J. P., Eisenhardt, K. M., & Bingham, C. B. (2007). Developing theory through simulation methods. *The Academy of Management Review, 32*(2), 480–499.
de Dreu, C. K. W., & Gelfand, M. J. (2007). Conflict in the workplace: Sources, functions, and dynamics across multiple levels of analysis. In C. K. W. De Dreu & M. J. Gelfand (Eds.), *The psychology of conflict and conflict management in organizations* (pp. 3–54). Mahwash: Lawrence Erlbaum.
de Dreu, C. K. W., & Weingart, L. R. (2003). Task versus relationship conflict, team performance, and team member satisfaction: A meta-analysis. *Journal of Applied Psychology, 88*(4), 741–749.
de Wit, F. R. C., Greer, L., & Jehn, K. A. (2012). The paradox of intragroup conflict: A meta-analysis. *Journal of Applied Psychology*, *97*(2), 360–390.
Erez, M., Earley, P. C., & Hulin, C. L. (1985). The impact of participation on goal acceptance and performance: A two-step model. *Academy of Management Journal, 28*(1), 50–66.
Furumo, K. (2009). The impact of conflict and conflict management style on deadbeats and deserters in virtual teams. *Journal of Computer Information Systems, 49*(4), 66–73.
Gist, M. E., Locke, E. A., & Taylor, M. S. (1987). Organizational behavior: Group structure, process, and effectiveness. *Journal of Management, 13*(2), 237–257.
Greer, L. L., & Dannals, J. (2017). Conflict in teams. In R. Rico, E. Salas, & N. Ashkanasy (Eds.), *The Wiley Blackwell handbook of team dynamics, teamwork, and collaborative working* (pp. 317–344). Somerset: Wiley Blackwell.
Greer, L. L., Jehn, K. A., & Mannix, E. A. (2008). Conflict transformation: A longitudinal investigation of the relationships between different types of intragroup conflict and the moderating role of conflict resolution. *Small Group Research, 39*(3), 278–302.

Guenter, H., van Emmerik, H., Schreurs, B., Kuypers, T., van Iterson, A., & Notelaers, G. (2016). When task conflict becomes personal: The impact of perceived team performance. *Small Group Research, 47*(5), 569–604.

Harrison, J. R., Lin, Z., Carroll, G. R., & Carley, K. M. (2007). Simulation modeling in organizational and management research. *Academy of Management Review, 32*(4), 1229–1245.

Hughes, H. P., Clegg, C. W., Robinson, M. A., & Crowder, R. M. (2012). Agent-based modelling and simulation: The potential contribution to organizational psychology. *Journal of Occupational and Organizational Psychology, 85*(3), 487–502.

Humphrey, S. E., & Aime, F. (2014). Team microdynamics: Toward an organizing approach to teamwork. *The Academy of Management Annals, 8*(1), 443–503.

Humphrey, S. E., Aime, F., Cushenbery, L., Hill, A. D., & Fairchild, J. (2017). Team conflict dynamics: Implications of a dyadic view of conflict for team performance. *Organizational Behavior and Human Decision Processes, 142*, 58–70.

Ilgen, D. R., Hollenbeck, J. R., Johnson, M., & Jundt, D. (2005). Teams in organizations: From input-process-output models to IMOI models. *Annual Review of Psychology, 56*(1), 517–543.

Jehn, K. A. (1995). A multimethod examination of the benefits and detriments of intragroup conflict. *Administrative Science Quarterly, 40*(2), 256–282.

Jehn, K. A. (1997). A qualitative analysis of conflict types and dimensions in organizational groups. *Administrative Science Quarterly, 42*(3), 530–557.

Jehn, K. A., & Bendersky, C. (2003). Intragroup conflict in organizations: A contingency perspective on the conflict-outcome relationship. *Research in Organizational Behavior, 25*, 187–242.

Jehn, K. A., & Mannix, E. A. (2001). The dynamic nature of conflict: A longitudinal study of intragroup conflict and group performance. *The Academy of Management Journal, 44*(2), 238–251.

Jehn, K. A., Northcraft, G. B., & Neale, M. A. (1999). Why differences make a difference: A field study of diversity, conflict and performance in workgroups. *Administrative Science Quarterly, 44*(4), 741–763.

Jehn, K. A., Rispens, S., & Thatcher, S. M. (2010). The effects of conflict asymmetry on work group and individual outcomes. *Academy of Management Journal, 53*(3), 596–616.

Jehn, K. A., Rispens, S., Jonsen, K., & Greer, L. (2013). Conflict contagion: A temporal perspective on the development of conflict within teams. *International Journal of Conflict Management, 24*(4), 352–373.

Jones, S., Shah, P. P., Ferguson, A., & Peterson, R. S. (2019). Things are not always what they seem: The origins and evolution of intragroup conflict. *Academy of Management Proceedings, 2019*(1), 11498.

Katzenbach, J. R., & Smith, D. K. (1993). *The wisdom of teams: Creating the high performance organization*. Boston: Harvard Business School Press.

Knight, D., Pearce, C. L., Smith, K. G., Olian, J. D., Sims, H. P., Smith, K. A., & Flood, P. (1999). Top management team diversity, group process, and strategic consensus. *Strategic Management Journal, 20*(5), 445–465.

Korsgaard, M. A., Soyoung Jeong, S., Mahony, D. M., & Pitariu, A. H. (2008). A multilevel view of intragroup conflict. *Journal of Management, 34*(6), 1222–1252.

Korsgaard, M. A., Ployhart, R. E., & Ulrich, M. D. (2014). The emergence of intragroup conflict: Variations in conflict configurations. In O. B. Ayoko, N. M. Ashkanasy, & K. A. Jehn (Eds.), *Handbook of conflict management research* (pp. 51–65). Cheltenham: Edward Elgar Publishing.

Kozlowski, S. W. J. (2015). Advancing research on team process dynamics: Theoretical, methodological, and measurement considerations. *Organizational Psychology Review, 5*(4), 270–299.

Kozlowski, S. W. J., & Chao, G. T. (2012). The dynamics of emergence: Cognition and cohesion in work teams. *Managerial and Decision Economics, 33*(5–6), 335–354.

Kozlowski, S. W. J., & Klein, K. J. (2000). A multilevel approach to theory and research in organizations: Contextual, temporal, and emergent processes. In K. J. Klein & S. W. J. Kozlowski (Eds.), *Multilevel theory, research and methods in organizations: Foundations, extensions, and new directions* (pp. 3–90). San Francisco: Jossey-Bass.

Kozlowski, S. W. J., Chao, G. T., Grand, J. A., Braun, M. T., & Kuljanin, G. (2013). Advancing multilevel research design: Capturing the dynamics of emergence. *Organizational Research Methods, 16*(4), 581–615.

Kurtzberg, T. R., & Mueller, J. S. (2005). The influence of daily conflict on perceptions of creativity: A longitudinal study. *International Journal of Conflict Management, 16*(4), 335–353.

Lee, S., Kwon, S., Shin, S. J., Kim, M., & Park, I. J. (2018). How team-level and individual-level conflict influences team commitment: A multilevel investigation. *Frontiers in Psychology, 8*, 2365.

Lewis, K., & Herndon, B. (2011). Transactive memory systems: Current issues and future research directions. *Organization Science, 22*(5), 1254–1265.

Lovelace, K., Shapiro, D. L., & Weingart, L. R. (2001). Maximizing cross-functional new product teams' innovativeness and constraint adherence: A conflict communications perspective. *Academy of Management Journal, 44*(4), 779–793.

Maltarich, M. A., Kukenberger, M., Reilly, G., & Mathieu, J. (2018). Conflict in teams: Modeling early and late conflict states and the interactive effects of conflict processes. *Group & Organization Management, 43*(1), 6–37.

McGrath, J. E. (1964). *Social psychology: A brief introduction*. New York, NY: Holt, Rinehart, & Winston.

McGrath, J. E. (1984). *Groups: Interaction and performance*. Englewood Cliffs: Prentice-Hall.

Michinov, N., & Michinov, E. (2009). Investigating the relationship between transactive memory and performance in collaborative learning. *Learning and Instruction, 19*(1), 43–54.

Mooney, A. C., Holahan, P. J., & Amason, A. C. (2007). Don't take it personally: Exploring cognitive conflict as a mediator of affective conflict. *Journal of Management Studies, 44*(5), 733–758.

Neck, C. P., Stewart, G. L., & Manz, C. C. (1996). Self-leaders within self-leading teams: Toward an optimal equilibrium. *Advances in Interdisciplinary Studies of Work Teams, 3*, 43–65.

Olson, B. J., Parayitam, S., & Bao, Y. (2007). Strategic decision making: The effects of cognitive diversity, conflict, and trust on decision outcomes. *Journal of Management, 33*(2), 196–222.

Palazzolo, E. T., Serb, D. A., She, Y., Su, C., & Contractor, N. S. (2006). Co-evolution of communication and knowledge networks in transactive memory systems: Using computational models for theoretical development. *Communication Theory, 16*(2), 223–250.

Parayitam, S., & Dooley, R. S. (2007). The relationship between conflict and decision outcomes: Moderating effects of cognitive-and affect-based trust in strategic decision-making teams. *International Journal of Conflict Management, 18*(1), 42–73.

Parayitam, S., & Dooley, R. S. (2009). The interplay between cognitive- and affective conflict and cognition- and affect-based trust in influencing decision outcomes. *Journal of Business Research, 62*(8), 789–796.

Parayitam, S., & Dooley, R. S. (2011). Is too much cognitive conflict in strategic decision-making teams too bad? *International Journal of Conflict Management, 22*, 342–357.

Pelled, L. H., Eisenhardt, K. M., & Xin, K. R. (1999). Exploring the black box: An analysis of work group diversity, conflict, and performance. *Administrative Science Quarterly, 44*(1), 1–28.

Peterson, R. S., & Behfar, K. J. (2003). The dynamic relationship between performance feedback, trust, and conflict in groups: A longitudinal study. Organizational Behavior and Human Decision Processes, 92(1–2), 102–112.

Pondy, L. R. (1967). Organizational conflict: Concepts and models. *Administrative Science Quarterly, 12*(2), 296–320.

Puck, J., & Pregernig, U. (2014). The effect of task conflict and cooperation on performance of teams: Are the results similar for different task types? *European Management Journal, 32*(6), 870–878.

Qian, C., Cao, Q., & Takeuchi, R. (2013). Top management team functional diversity and organizational innovation in China: The moderating effects of environment. *Strategic Management Journal, 34*(1), 110–120.

Schweiger, D. M., & Sandberg, W. R. (1989). The utilization of individual capabilities in group approaches to strategic decision-making. *Strategic Management Journal, 10*(1), 31–43.

Simons, T. L., & Peterson, R. S. (2000). Task conflict and relationship conflict in top management teams: The pivotal role of intragroup trust. *Journal of Applied Psychology, 85*(1), 102–111.

Smith, E. R., & Conrey, F. R. (2007). Agent-based modeling: A new approach for theory building in social psychology. *Personality and Social Psychology Review, 11*(1), 87–104.

Stark, E. M., & Bierly, P. E., III. (2009). An analysis of predictors of team satisfaction in product development teams with differing levels of virtualness. *R&D Management, 39*(5), 461–472.

Tajeddin, G., Safayeni, F., Connelly, C. E., & Tasa, K. (2012). The influence of emergent expertise on group decision processes. *Small Group Research, 43*(1), 50–74.

Tajfel, H., & Turner, J. C. (1979). An integrative theory of intergroup conflict. In W. G. Austin & S. Worchel (Eds.), *The social psychology of intergroup relations* (pp. 33–47). Monterey: Brooks/Cole.

van Knippenberg, D., & Hoever, I. J. (2018). Team diversity and team creativity: A categorization-elaboration perspective. In R. Reiter-Palmon (Ed.), *Team creativity and innovation* (pp. 41–59). New York, NY: Oxford University Press.

van Knippenberg, D., de Dreu, C. K. W., & Homan, A. C. (2004). Work group diversity and group performance: An integrative model and research agenda. *Journal of Applied Psychology, 89*(6), 1008–1022.

Wegner, D. M. (1987). Transactive memory: A contemporary analysis of the group mind. In *Theories of group behavior* (pp. 185–208). New York,NY: Springer.

Wegner, D. M. (1995). A computer network model of human transactive memory. *Social Cognition, 13*(3), 319–339.

Wegner, D. M., Giuliano, T., Hertel, P., & Ickes, W. J. (1985). Cognitive interdependence in close relationships. In W. Ickes (Ed.), *Compatible and incompatible relationships* (pp. 253–276). New York, NY: Springer-Verlag.

Wilensky, U. (1999). *NetLogo*. Evanston: Northwestern University, Center for Connected Learning and Computer-Based Modeling. Retrieved October 1, 2018, from http://ccl.northwestern.edu/netlogo/

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.